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The Reproducibility and Accuracy of Internal Fit of Cerec 3d Cad/cam all Ceramic Crowns

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Abstract - *The objective of this study was to evaluate the reproducibility and accuracy of internal fit using Cerec 3D CAD/CAM (computer aided design/computer aided manufacturing) all-ceramic crowns and to investigate the proximal contact point areas between the crowns and neighbouring teeth, in terms of location and the presence or absence of contact. A total of 48 crowns were milled and divided into two groups of twenty-four each. One group consisted of testing a Control die and the other group consisted of testing single Replica stone die duplicates of the Control die. The Internal Marginal Gap, Axio-Occlusal Transition Gap and Occlusal Gap were measured on each crown in both groups. No significant differences were identified between the mean thickness of the Marginal Gap, the Axio-Occlusal Transition Gap and the Occlusal Gap of the Control die when compared with the Replica dies indicating uniformity and consistency of the accuracy of fit and therefore die replication.*

KEY WORDS: Cerec 3D CAD/CAM, Accuracy of Fit, Proximal Contacts

INTRODUCTION

Machined ceramics that used CAD/CAM technology were introduced to create long-term dental restorations with adequate clinical marginal accuracy and also to reduce the time and expense needed to fabricate dental restorations. CAD/CAM is an acronym for computer aided design/computer aided manufacturing and it refers to the use of computers and software in both the design and manufacturing of a product. The earliest type of CAD/CAM technology was developed in 1980 by the combined efforts of W.H. Mörmann (clinician), and Marco Brandestini (electrical engineer) and was known as Cerec ("Computer assisted CERamic RECon-struction,"). This machine proposed to significantly reduce the time required to fabricate restorations, thus permitting clinicians to treat patients in single appointments. An optical impression was taken of the prepared single unit in the patient's mouth using a Charge Coupled Device (CCD)[1]. Mörmann and Brandestini focused on using technical requirements for surveying the optical impression in the patient's mouth. These requirements included taking the impression without touching the preparation, supporting the camera bimanually on the dental arch, single exposure from a single camera viewing angle, operating the camera without the use of reference markings on the teeth, and being able to reproduce impressions quickly[2].

The first Cerec chairside treatment began in 1985 at the University of Zurich, Switzerland[2].

The developments of machined ceramics lead to the introduction in 1992 of the Cerec 1 model, which was an updated version of the original Cerec using an electric motor to drive the milling machine. In 1994 the Cerec 2 was introduced which used a diamond coated disc on the right side to mill the restoration and on the left a diamond bur was positioned which was capable of milling occlusal surfaces although was still inadequate for milling the inside surfaces of crowns. The main difference between Cerec 1 and Cerec 2 was the development of a computer integrated imaging and milling unit with the restorations designed on a computer screen[3,4].

Coinciding with the approach of the new millennium Cerec 3 was released in 2000, which was a Windows based (Microsoft Corporation, USA) restorative system, resulting in user-friendly software unlike earlier Cerec systems. The Cerec 3 system comprises a grinding unit with a separate flat screen with a three dimensional measuring camera and updated Cerec 3 software[4,5,6,7,8]. Microsoft's programme Windows NT was used to write the construction and control software and could be run using a personal computer (PC) integrated into the recording unit. This new software development eliminated the lengthy time spent for picture adjustment, and data storage. The separate milling unit operated with two cylinders, which differed from the earlier Cerec machines, which used a disc. These two cylindrical diamond burs were 1.2mm or 1.6mm with a 45-degree taper angle on top, this provided the creation of detailed occlusal surfaces minimising the time in manually finishing the occlusion[7]. The latest addition to Cerec technology is Cerec 3D CAD/CAM, which was introduced by Sirona Dental Systems in 2003 at the Hinman Dental Meeting in Atlanta, USA. Since that time the software of the Cerec 3D CAD/CAM system has been continually updated.

The evolution of Cerec 3D technology identifies areas of improvement over earlier Cerec systems. The main difference being that the Cerec 3D software is far more user friendly, resulting in fewer steps taken and ease of design of dental restorations on the computer screen by the clinician. With the continued updating of the Cerec 3D software, the porcelain blocks used in the milling stage have also

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continued to develop. New features in the Cerec 3D software have also allowed the ease and precision of creating the margin line on the preparation since the margins are created automatically by the software, which minimises the risk of operator error**.**

A variety of shades are now available that can be custom-stained and glazed after the restoration is milled and the use of CAD/CAM technology have been extended from inlays/onlays and single restorations to a more complex multi-unit rerstorations[9,10,11,12,13,14,15].

The purpose of this study was to test the accuracy of internal fit using Cerec 3D CAD/CAM all ceramic crowns, and to analyze the proximal contact point areas between the crowns and neighbouring teeth, in terms of location and the presence or absence of contact.

MATERIALS AND METHODS

The Control Die prepared for this experiment was a Mandibular first molar from a manikin Mandibular arch (Frasaco). The Control Die was prepared with dimensions of 1mm marginal reduction, 1.5mm reduction on the Occlusal, Buccal, Lingual, Mesial and Distal edges and 90° Shoulder margin. Twenty-four separate impressions were taken of the Control Die, using the silicone putty and wash technique.

The impressions were poured using a high strength die stone (Jade Stone). The material was vacuum mixed and poured in each separate impression. The dies were then separated from the impression after 30 minutes and the rough edges were removed using a diamond disc. An optical image was obtained for the prepared mandibular first molar using the Cerec Oral camera. The scanned impression of the preparation was used to design the crown(s) on the computer screen which were then milled in the milling unit of the Cerec machine using a fine-particle feldspar ceramic blocks (VITABLOCKS Mark II). The internal gap between each crown and die was quantified by measuring the thickness of a coating of a White VPS Silicone (Fit Checker) that was applied between the inner surface of the crown and the surface of the die as detailed below.

For each crown, an equal amount of White VPS Silicone Base and Catalyst (1cm) was placed on a mixing paper pad and mixed thoroughly for 20 seconds. The mixture was then applied to the inner surface of the crown and the fitting surface of the die. Using finger pressure the crown and die were held together and the excess silicone was removed before the material set. The crown was then removed from the die leaving a coat of silicone on the surface of the die. This procedure was repeated on each separate Replica stone die, and also repeated twenty-four times on the Control Die.

The silicone impression material was mixed according to manufacturer instructions. Two separate labelled and Vaselined impression trays consisting of twenty-four cylindrical containers of 16mm diameter were used. One tray was used for the Control Die impressions and the other for the Replica stone dies. The Replica stone die cylinders were half filled with Silicone regular body impression material and the stone dies, which were coated in White VPS Silicone, were submerged in each cylinder to cover the margin leaving the root protruding.

After the silicone impression material was set, each stone die was removed from the twenty-four cylinders leaving the White VPS Silicone embedded into the silicone. Regular body impression material was flowed smoothly into each cylinder covering the White VPS Silicone to the brim of the cylinder and allowed to set. The procedure was repeated 24 times for the Control Die in the second tray, *(Figure 1)*. Each specimen was removed from the cylindrical containers and sectioned using a razor blade. Each specimen was cut once in a Mesio-Distal direction. The gap between the die and restoration (White VPS Silicone) was then measured. The locations for gap measurements were the marginal gap (X), the axio-occusal transition gap (Y), and the occlusal gap (Z), *(Figure 2)*. Measurements were performed using a Travelling Microscope (Nikon) at a magnification of X50. The microscope was connected to a digital camera and had a software programme that allowed direct measurement between any two points in the projected image. The left side of each silicone block was used for measuring. Each of the twenty-four milled crowns for Replica and the Control groups were positioned on the Control die and placed in the Mandibular dental arch for assessment of proximal contacts.

The Mesial and Distal areas were separated for the purpose of assessment of the contact areas into nine sections (*Figure 3, 4*), (*Tables 1,2,3 & 4*).

Articulator paper (40µm) was used to identify contact point location on Mesial and Distal areas and dental Floss was

Figure 1. *Stages involved in the preparation of specimens for Internal Gap Measurements.*

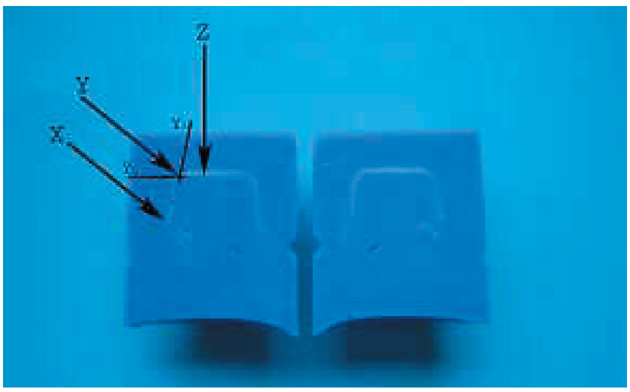

Figure 2. *locations of Internal Gap Measurements. "X" Marginal Gap, "Y" Axio-Occlusal Transitional Gap, "Z" Occlusal Gap.*

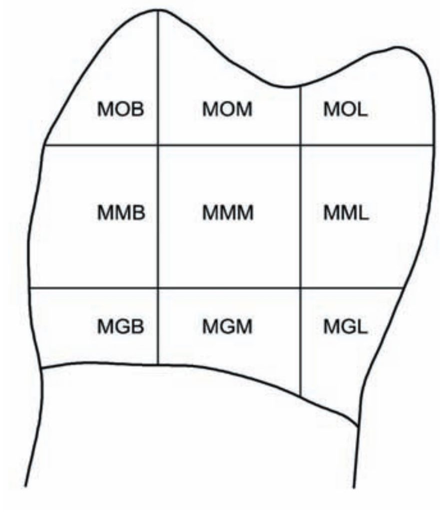

Figure 3. *Mesial sectioned areas.*

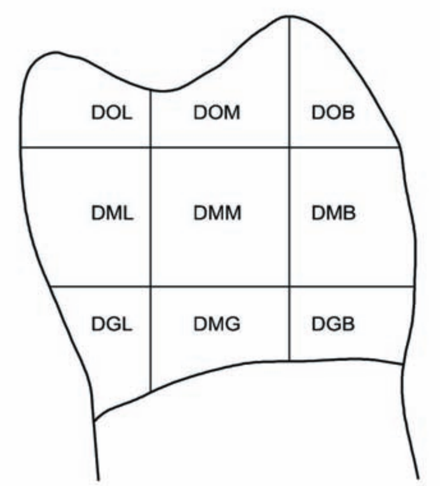

Figure 4. *Distal sectioned areas.*

used to test the tightness of each contact point. Shimstock (8µm) was used as a control for the tightness of each contact point.

RESULTS

Marginal Gap "X"

The Marginal Gap for the Control Die had a mean thickness and standard deviation of 149 ± 26µm and a minimum thickness value of 115 µm, with an associated maximum thickness of 231 µm. When the mean Marginal Gap thickness for each Replica die were analysed, the mean marginal thickness and standard deviation were 174 ± 48µm, the maximum thickness was 333 µm and the minimum thickness was 122 µm. The Student's-t-test revealed no significant difference between the mean Marginal Gap of the Control Die and the Replica Dies when assessed at the 95% confidence level.

Axio-Occlusal Transition Gap "Y"

The Cerec crowns seated on the Control Die produced an Axial-Occlusal Transition Gap, with a mean thickness and standard deviation of 208 ± 46µm. The Control die measured a minimum thickness of 146 µm and a maximum thickness of 337 µm. When the Cerec crowns were placed on each Replica Die the Axial-Occlusal Transition Gap had a mean thickness and standard deviation of 259 ± 92µm. The minimum thickness measured was143 µm and the maximum thickness measured was 477 µm. The Student t-test revealed no significant difference between the mean Axio-Occlusal Transition Gap of the Control Die and the Replica stone die when assessed at the 95% confidence level.

Occlusal Gap "Z"

The internal gap thickness beneath the occlusal surface of the Cerec crowns seated on the Control Die had a mean Occlusal Gap thickness and standard deviation of 254 ± 52µm, a maximum value of 382 µm with an associated minimum value of 168 µm. The Replica die had a mean Occlusal Gap thickness and standard deviation of 290 ± 125µm, a maximum thickness of 624 µm and a minimum thickness of 164 µm. The Student t-test revealed no significant difference between the mean Occlusal Gap of the Control die and the Replica stone die when assessed at the 95% confidence level.

The data for the contact point analysis for the Floss and Shimstock in the Mesial area of the Control Die highlighted contact points in mainly the Mesial Occlusal Middle (MOM) and Mesial Middle Middle (MMM) areas i.e. 67%, 33% using floss and 52%, 35% using shimstock for (MOM) and (MMM) contacts respectively. Interestingly, the results from the contact area analysis for the Floss and Shimstock in the Mesial area of the Replica dies were similar to the control, namely concentrated in Mesial Occlusal Middle (MOM) and Mesial Middle Middle (MMM) areas i.e. 61%, 36% using the floss and 56%, 32% using the shimstock for the (MOM) and (MMM) contacts respectively (Table 1 & 2). *(Figure 3)*

The data for the contact point analysis for the Floss and Shimstock on the Control die highlighted that the majority of contacts for the distal area were in Distal Occlusal Buccal (DOB) and Distal Middle Buccal (DMB) regions of the crown i.e. 47%, 40% of the contacts using floss and 33%,30% using shimstock for the (DOB) and (DMB) respectively. Although there was some contact points located in the Distal Middle Middle (DMM) area of the crown. When the data for the contact point analysis for the Floss and Shimstock on the Replica die were analysed the results identified a similar trend in the Distal area of each Replica die. The majority of contacts for the distal area were in Distal Occlusal Buccal (DOB) and Distal Middle Buccal (DMB) regions of the crown i.e. 43%, 30% using floss and 47%, 21% using shimstock for the (DOB) and (DMB) contacts respectively (Table 1 & 2). With some contact points located in the Distal Middle Middle (DMM) area of the crown, *(Figure 4)*.

When the non-parametric contact area data in the distal and mesial areas of the Control and Replica dies were examined by a non-parametric one-way ANOVA (Kruscal-Wallis) no significant difference between the contact areas in the Distal and Mesial areas of the Control and Replica dies was evident when assessed at the 95% confidence level, *(Table 1, 2, 3, & 4)*.

Table 1. *Contact areas locations and strength of contact determined using dental floss in the mesial and distal surfaces of crowns in the control group*

Floss on Control	*Distal Sections*			*Mesial Sections*	
Strength of contact on each crown	*DOB*	*DMB*	*DMM*	*MOM*	*MMM*
Strong	22	16	4	6	5
Weak		3		10	3
No Contact	1		1		

Table 2. *Contact areas locations and strength of contact determined using shimstock in the mesial and distal surfaces of crowns in the control group*

Shimstock on control	*Distal Sections*				*Mesial Sections*	
Strength of contact	*DOB*	*DMB*	*DMM*	*DGM*	*MOM*	*MMM*
Strong	9	7			12	4
Weak	6	7	3	1		4
No Contact	6	4	3		1	2

Table 3. *Contact area location and strength of contact determined using dental floss on crowns in the Replica group.*

Floss on Replica	*Distal Sections*				*Mesial Sections*		
Strength of contact	*DOB*	*DMB*	*DMM*	*DGM*	*MOM*	*MMM*	*MGM*
Strong	19	1	12	7	5	4	1
Weak	1	1	2	2	12	6	
No Contact	2						

Table 4. *Contact area location and strength of contact determined using Shimstock on crowns in the Replica group*

Shimstock on Replica	*Distal Sections*				*Mesial Sections*		
Strength of contact	*DOB*	*DOM*	*DMB*	*DMM*	*MOM*	*MMM*	*MGM*
Strong	11		4	4	8	3	
Weak	7	1	4	1	6	5	1
No Contact	2	1	2	1	2		

Abbreviations

Distal Area
Distal Occlusal Buccal (DOB)
Distal Middle Buccal (DMB)
Distal Middle Middle (DMM)
Distal Gingival Middle (DGM)
Distal Occlusal Middle (DOM)

Mesial Area
Mesial Occlusal Middle (MOM)
Mesial Middle Middle (MMM)
Mesial Gingival Middle (MGM)

DISCUSSION

No major difference was identified between the mean thickness of the Marginal Gap, the Axio-Occlusal Transition Gap and the Occlusal Gap of the Control die when compared with the Replica dies indicating uniformity and consistency of the accuracy of fit and therefore die replication. The results revealed that the replication technique used in this current study could be applied to produce Replica dies of Control dies.

When indirect techniques are used for fabricating crowns, there are many reasons why accuracy of fit may be affected such as: impression and model material deformities; wax irregularities or shrinkage from porcelain high firing cycles[5,]. However since Cerec 3 ceramic blocks do not have to be subjected to high temperatures in the milling process, heat dimensional changes will not occur which can lead to better fit results. There have been many studies into the clinically acceptable size of marginal gaps. Early studies have suggested that marginal gaps should be in the range of 25-40µm. However recent studies have shown that clinically acceptable margin gaps may be as big as 300µm [11,13,,16,17,18]. Some of the marginal gaps examined in this study were clearly not acceptable for clinical use, although these measurements were similar on the Control and Replica crowns verifying reproducibility. A similar study into the accuracy of fit of Cerec 3 crowns by Nakamura et al[5] examined the occlusal Convergence Angle of the abutment and the computer luting space setting to test the reproducibility. The study concluded that crowns with a good fit could be produced using the Cerec 3 system when the luting space was adjusted to 30µm.

Obtaining an acceptable contact areas with teeth adjacent to those being restored with direct or indirect restorations is a requirement that can be challenging to the clinician since it is likely to be influenced by a number of factors including the operator's experience and technique used[19,20,21]. In the present investigation no significant differences were found between Mesial and Distal proximal contact areas on Control and Replica crowns highlighting the consistency of contact point placement upon neighbouring teeth. This could possibly be due to the fact that the current CAD/CAM system removes some of the factors that can influence the contact areas when using non CAD/CAM or conventional techniques.

CONCLUSIONS

Within the limitations of this study it could be concluded that there were no significant differences in the marginal gaps, the axio-occlusal transition gaps and the occlusal gaps of the Control and Replica Dies investigated. No significant differences in the position and tightness of the contact areas were found between the mesial and distal surfaces of the control and replica dies.

MANUFACTURERS' DETAILS

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- Coltene Whaledent AG, Alstatten, Switzerland
- Frasaco Dentoform Corporation,Germany
- GC Dental Products Corp. Aichi , Japan
- Hanel, Langenau, Germany
- Johnson & Johnson, U.K.
- Nikon, Mitatoyo Corporation, Japan
- Whip Mix Corporation, Kentucky, U.S.A

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